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geal, causes a copious secretion of mucus. In the last case there is no secretion of mucus when the vagi are divided. Perhaps the result is due to a reflex secretion, the reflex centre being in the bulb, while the vagus is the efferent channel for the impulses affecting the secretory glands. In birds also it would appear that the vagus influences the secretion of gastric juice. Oxenfeld finds that in birds (pigeons) stimulation of the peripheral end of the vagus is followed by a copious secretion of acid gastric juice. At the same time the stomach is forcibly contracted, and it might be assumed that the increased quantity of gastric juice was simply forced out of the glands by the concentration of the musculature of the stomach. Oxenfeld, however, is of opinion that this is not the true explanation, and he assumes that the vagus contains secretory fibres for the gastric glands.

LETTERS TO THE EDITOR.

** Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.

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The editor will be glad to publish any queries consonant with the character of the journal.

How Children Learn to Talk.—A Study in the Development of Language.—Children's Vocabularies.

PHILOLOGISTS and others interested in the origin of language and the development of intellect find very striking analogies between the development of speech and intelligence in the race and in the child, and have obtained some very valuable hints as to the laws determining the growth of language. Scientific psychologists and educators have also gained many important truths from the study of children. A much more extensive and detailed study, however, is now necessary to further progress in either line.

The first thing to be done in every scientific investigation is to collect a large number of reliable facts, from which generalizations may be made and theories found that will guide the investigator in further researches, and lead to the discovery and unification of a general law of nature that can usually be turned to practical account by the inventor, educator, or legislator. Facts of every kind in regard to development of intelligence in children and their progress in language are important, and in the earlier stages of the investigation the common and ordinary facts rather than the unusual and extraordinary are the most valuable. For the purpose of securing such facts and arousing interest in the study of children I wrote an article some months ago entitled "Children as Teachers," and published it in a number of papers. The records sent me in response to the request in that article are very interesting and suggestive. Many interested in the subject, however, doubtless overestimated the difficulty of securing valuable records, and therefore I have not yet received a sufficient number of records to justify me in making a full report, as I had promised, at present. The records so far examined serve to bring out the great individual differences in children rather than to show what is common to all, yet they are common characteristics suggestive of general laws sufficient to confirm me in the belief that a comparison of a number of such records will give very valuable results.

A convenient method for those who cannot keep a daily record of a child's progress in language was adopted by some reporting to me. During a certain period special attention was paid to the child's language, and all words the child was known to use understandingly were noted down in alphabetical order (the child's pronunciation of the words being indicated as nearly as possible), and this was taken as the child's vocabulary at that age. A few months later the process was repeated, and the progress that had been made could then readily be seen by comparing the two records.

The number of words used by children two years old differs considerably, but is usually larger than parents supposed. The number varies from a very few words for the child who is backward in learning to talk, though perhaps not less intelligent otherwise, up to a thousand words for children more precocious in that

particular. Judging from the records in my possession, from two to four hundred words is the more common number.

The rate at which new words are acquired varies greatly for different children and at different ages. After they are once fairly started in learning language, it is usually quite rapid, especially with those who are late in beginning to talk. For children just past two years of age, from sixty to one hundred words per month seems to be a common number. If new words should continue to be acquired at this rate until maturity, as they probably are by those who study and read much, an adult would have a vocabulary of from 15,000 to 25,000 words (see "Size of an Ordinary Vocabulary," *Science*, Aug. 21, 1891). The additional words used by a child do not represent all of his progress in language. He may have learned the meaning of many words he has had no occasion to use; he may have learned something about forming plurals and the different parts of verbs, and considerable about how to put words together in sentences. The progress in the latter respect may be shown by keeping a record of his characteristic attempts at sentence making, being careful to omit sentences that are evidently repeated from memory.

The part of speech most used by children seems to be the noun. About 60 per cent of the words in the English language are nouns, 22 per cent adjectives, 11 per cent verbs, and 5½ per cent adverbs, while conjunctions, prepositions, and pronouns form but an insignificant portion of the whole. In an ordinary vocabulary, taking "Robinson Crusoe" as the standard, the proportion of nouns is smaller, and in a still smaller vocabulary there seems to be occasion for the use of a greater variety of verbs than nouns, and a necessity for the use of a number of prepositions, pronouns, and conjunctions. On a page of "Robinson Crusoe" containing 215 different words, but 24 per cent were nouns. Hence the fact that in a child's vocabulary of a few hundred words from 55 to 85 per cent of them are nouns, while but few of the prepositions, pronouns, and conjunctions that it hears repeated so frequently are used, is quite significant. Nouns, however, are not always learned easier and earlier than other parts of speech, for such a verb as "come," or adjective as "hot," may be among the first words learned. Any word which can be associated with a distinct, sensible experience can readily be learned, but abstract terms are not found in children's vocabularies.

General terms are used by children, at quite an early age, with some degree of correctness, though of course all that is connotated or included under a general term is not understood by any one until its scientific meaning is known. A general term is applied to all individuals having certain characteristics, though they may differ in other respects. The accuracy with which a child uses general terms depends upon the distinctness of his ideas of the special characteristics to which the term is applied, and his power of noting and discriminating those special qualities among a variety of others. His attainments in these two respects are limited by his previous experience. A child who calls a goat a "dog" may lack in clearness of conception of the characteristics of dogs, or in his powers of discrimination, or only in experience. In the latter case he classifies it with the group of animals it resembles more closely than any others with which he is acquainted. A child of twenty-six months who found a small crab in her oyster soup classified it at once with the group of animals it seemed to her to most resemble, and called it a "bug," then performing a considerable act of inference, she gave it the more definite name "oyster-bug." A little girl of less than eighteen months, who learned the word "cut" in connection with the use of a knife, not only called all knives "cutie," but applied the same term to shears when she saw the same operation performed with them, and later to a sickle with which grass was being cut. Nothing is more interesting or important in the study of children than the way in which they generalize, classify, and infer, and instances of such childish judgments and inferences, so odd to us, yet really so natural and logical from their point of view, should be carefully noted and recorded.

Children sometimes form a language of their own entirely different from that of their parents. This is more likely to occur with children of the same age, especially if they are alone together much. Instances are known of children forming apparently quite

complete vocabularies, and using no other for several years. This tendency to originate language is shown in almost every child by the invention of new words or new uses for words. New terms are often formed by imitating the noise made by the animal or thing named, as "bow-wow" for dog, "choo-choo" for locomotive, and sometimes by the repetition of a sound made in performing an act, or an emotional sound made at sight of a new object or act. Any sound thus associated with an object, act, quality, or state of feeling may be used by the child as a word, and, if the parents or playmates accept it as having a certain significance, it becomes fixed as a permanent part of the child's vocabulary.

Baby talk, or the peculiar pronunciation used by children, and frequently imitated in literature, is a subject of considerable interest. How much of what is given as "baby talk" has really been originated by children? How much of the incorrect pronunciation of any particular child is due to his inability to pronounce correctly, and how much to the foolish habit of mispronouncing words when speaking to children practised by so many fond parents? Of still more importance is it to know whether there really is any general law of mispronunciation that may be of practical value to the educator. In only a part of the records sent me was the pronunciation used by the child indicated, hence only the probabilities in regard to the law can be given. In the first place, it must be understood that the ability to pronounce words is entirely independent of the ability to understand their meaning, and either capacity may be developed in advance of the other. However, in the acquirement of new words, difficulty of pronunciation may exercise some influence in preventing the adoption of certain words into the vocabulary. Not all children are influenced in this way; some adopt difficult words but use a sound easily pronounced in place of the one they cannot pronounce, sometimes following a regular system of substitution. The law of mispronunciation proposed by Noble (*Education*, 1888) seems theoretically quite probable, and some of the facts support it, but not enough have been collected to establish it. He reasons that correct pronunciation depends upon clear perception of the sounds to be uttered and a knowledge of the motions necessary to produce them. The knowledge of the proper movements to be made are partly gained by watching the motions made by others in speaking. On imitating the sound the errors in movement are detected and corrected by comparing the resulting sound with the sound heard. The sounds then that are most distinctly pronounced and requiring movements that are the most clearly visible will naturally first be learned and be most clearly pronounced. Those made in the front part of the mouth, such as labials and dentals, fulfil both of these conditions, while those made in the back part of the mouth usually fulfil neither of them. This law, if approximately true, must yet be modified by the fact that children can usually make every one of the elementary sounds used in language before they begin to talk. The difficulty in pronouncing a word is not to utter the elementary sounds of which it is composed, but to properly combine them. As in learning other complex series of motions, it is not a question of making any one motion, but of properly co-ordinating a series of simple motions. No one has any difficulty in pronouncing such words as "three," and "gray," and "geese" separately, but many do in pronouncing them rapidly one after the other. For a similar reason a child who can pronounce perfectly a sound in one word is wholly unable to utter it in another. Besides this, sounds are modified somewhat by the sounds that precede and follow them. Almost every one also slurs some sounds in his pronunciation, and children frequently notice and try to imitate only the most distinctly pronounced sounds. They therefore often mispronounce, not from inability to utter the sounds, but because they have failed to notice some of the less perfectly pronounced ones. Since sounds made at the beginning of words are least modified by other sounds, mispronunciation can best be studied in the initial sounds of words. The letter with which a word begins usually, but not always, indicates the sound. The following is the order for the letters appearing most frequently as initial letters in children's vocabularies: s, b, c, p, t, w, d, m, h, f, r, l, g, n. To understand the significance of this, it must be compared with the order of frequency for the difficult letters in the dictionary (s, p, c, a, t, b, r, m, d, f, e, h, l, g), and

in "Robinson Crusoe" (s, c, p, a, f, b, r, m, e, t, w, h, l, i, g). One of the most marked differences is the greater number of words beginning with the dentals *b* and *d* to be found in the vocabularies of children.

Many very interesting questions were suggested by the study of the records already sent me, but a much larger number of vocabularies must be compared before reliable answers can be obtained. I shall be glad to receive such records at any time, or to communicate with any one in regard to methods of carrying on the study of children. Letters directed to Rhodes, Iowa, will always reach me.

E. A. KIRKPATRICK.

Rhodes, Io., Sept. 14.

The Convection Theory of Storms.

DR. HANN of Vienna has published recently an extended discussion of this subject, and one which has the extremest significance (*Sitzber. d. kais. Akad. d. Wissensch. in Wien*, April, 1891). He reiterates his view that in our storms at heights of 10,000 feet there is a fall in temperature, and a corresponding rise in our high areas. These points have been sufficiently answered already (*Science*, Vol. XVI., p. 136). The remaining discussion merits our attention, as it presents a rather strong attack upon the theories ordinarily accepted. A free translation of the argument is here given. Dr. Hann says:

"How can we think that such extremely flat disks as the great storms of the higher latitudes are can maintain themselves and advance through a rising of air particles. Our whirls have often more than a hundred times greater extension horizontally than vertically. Doberck gives this ratio as 250:1. A chimney, as is well known, draws only when its height is many times greater than its interior diameter. But in our whirls the relation is in a most extreme manner opposite. How such an exceedingly flat air-disk, only through an interior force, that is, through a freeing of latent heat by a local interior moisture condensation, can move itself in the atmosphere, appears to me difficult to understand. The whole height of the atmosphere (so far as it can come into consideration for the condensation theory) at the utmost is small as compared to the horizontal diameter of our whirl (above 25,000 feet is there no moisture). I do not know that the convection theory has seriously considered this objection. This objection does not hold against the theory that correlates the whirl with disturbances in the general circulation currents of the atmosphere.

"A fact which stands out in sharp contradiction with the plain convection theory of our storms lies in the yearly period of their frequency and intensity. If the convection theory is clearly applicable to most of our storms, how can it be that these storms have their greatest intensity and frequency in the winter, even at a time of the year when the conditions, as well for their origin as for their continuance, are most unfavorable?

"In winter the moisture of the air is slight and the thermic equilibrium most stable. Upon the continents the lowest layers are often for a long time the coldest, and the temperature increases above. The heat diminution with height is very small in winter, even less than in a rising air current due to the distribution of moisture. How can a whirl under such conditions of the convection theory reach to the interior of Siberia, where the temperatures are -22° F. to -40° F., and there is no moisture. It is an inevitable consequence of the convection theory that the cyclones of the summer must reach their greatest intensity and frequency, because at this time the moisture of the air is greatest, the heating of the lowest layers the most active, and the heat diminution with height in consequence the most rapid.

"In fact, heat thunder-storms and tropical cyclones, the appearances to which rightly the convection theory can find application, are limited to the warm season. Tropical cyclones reach a maximum of occurrence at a time when the temperature of the sea is highest, or when a generally uniform air pressure and the absence of strong air currents favor largely the development as well as the advance of such whirls, which, perhaps, have for the great part their driving force in themselves. Also the heat thunder-storms or thunder-storm whirls of our summers occur most